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CONSERVATION

Research and conservation of historic decorative schemes in the built environment

MOTION PROJECT MANAGEMENT

Materials Analysis: Paint, Stucco & Window Joinery

Manchester Opera House

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1.0: Introduction

Lincoln Conservation was commissioned by Motion Project Management to carry out paint research on the façade and windows of The Opera House, Manchester. Additional analysis was carried out to determine the window timber species and nature of the stucco render on the façade.

Figure 1: The Opera House façade facing the road

Architectural Paint Research is a technique widely used to help define the decorative history of historic buildings and other structures. It is an evidence-based approach that relies on the microscopic examination of small samples of paint removed from key locations. Sample locations are carefully selected to yield as much information as possible (the thickest paint layers) and include a portion of substrate (in this case, wood and render) to ensure a complete historical record is examined.

With the decorative history of an historic building revealed, the client is provided with the evidence needed to make informed decisions about how a building should be presented to reflect its past appearance. With sufficient evidence, it may be possible to faithfully recreate the appearance of a historic building at some point in its past; or if information is lacking or fragmentary there is normally enough evidence to reintroduce a flavour of its decorative appearance and extrapolate the colour schemes onto areas of later repair.

1.1: History of the building

The Opera House is a Grade II listed building built in 1912 by Horace Farquharson and Richardson and Gill in a Neo-classical style[1]. It operated mainly as a theatre (with a brief stint as a cinema in WW2) until the late 1970s, when it was run as a bingo hall for several years, before being re-opened as a theatre again in 1984[2]. The building was most recently refurbished in 2003[3].

[1] https://historicengland.org.uk/listing/the-list/list-entry/1247470?section=official-list-entry
[2] http://www.arthurlloyd.co.uk/ManchesterTheatres/OperaHouseManchester.htm
[3] http://manchesteroperahouse.com/

Figure 2: Detail of a drawing of the Opera House (then known as the New Theatre) by Hanalip Fletcher, from The Guardian, 26th December 1912 (source: https://www.newspapers.com)

Figure 3: The Opera House in 1913 (source: Historic England)

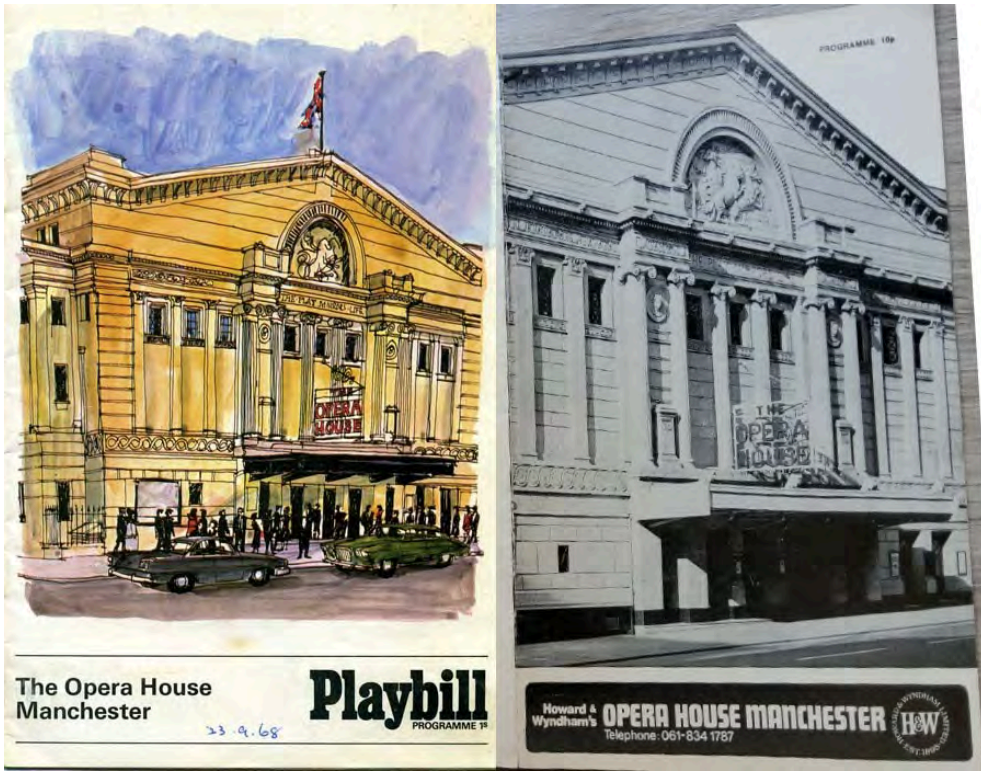


Figure 4: Details from 1968 (left) and 1977 (right) Opera House theatre programmes (source: manchesterhistory.net)

2.0: Methodology

The samples, including substrate, are mounted in polyester resin in cross-section and polished back to reveal the full stratigraphy of the paint layers applied. The earliest paint layers appear at the bottom of the sample, with subsequent layers stacked above, as they would have been applied over time (similar to an archaeological record).

The sample is then viewed through a microscope at various magnifications under simulated daylight to determine the distinct layers of paint applied and to reveal colours. The presence of dirt layers helps to determine the separate decorative schemes – a scheme can be made up of more than one layer, commonly a primer and topcoat. Ultra-violet illumination causes different types of paint and varnishes to fluoresce (or glow) in a characteristic manner, helping to distinguish traditional oil paints (both lead and zinc based) from modern synthetic alkyds, distempers and varnish coatings.

3.0: How to read this report

These architectural paint research findings are presented in two formats:

- Annotated photomicrographs
- Discussion

<u>Annotated photomicrographs</u>

A photograph taken at high magnification through a microscope. Selected images are included in section 5.0 of this report. Some of them display a large number of paint layers, starting in the early 20th century with many others stacked above, up to the present day. Others show fewer layers, indicating areas that have been stripped or replaced. Where possible the timber or render substrate is included with the image, indicating a complete record has been examined.

<u>Discussion</u>

This summarises the research and provides the concluding remarks, with options for redecoration that re-introduces an earlier appearance of the building façade based on the evidence uncovered. If evidence is missing, sensible conclusions are drawn extrapolating the data uncovered, coupled with our extensive experience on similar buildings over many years.

4.0: Sample locations

Every sample removed carries a unique identifying number corresponding to the locations illustrated in this section of the report. Samples were removed from the external frames and casements of the windows that were accessible from ground level, but due to access issues, it was only possible to remove external samples from the upper-level frames and casements on selected windows. Samples were also removed from selected internal casements and frames on the upper levels for comparison, and several samples were removed from the railings outside, in case they could provide additional evidence of historic external decorative schemes. Four samples were removed from various decorative elements of the façade at ground level, but the guilloche mouldings on either side of the entrance appear to be modern resin replicas, so they were not sampled.

Figure 5: sample locations 1, 2 (windows W2-F and W3-F) & 18 – 20 (railings)

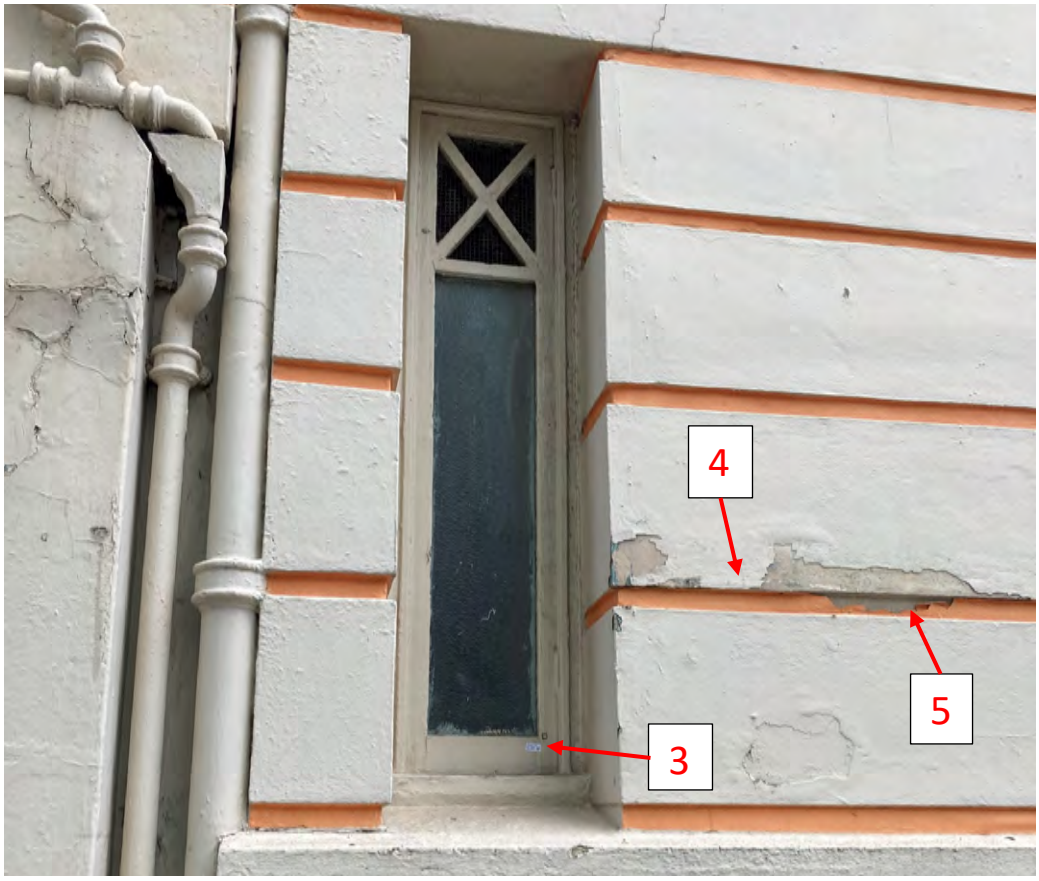


Figure 6: sample locations 3-5 (window W1-F and faux-ashlar blockwork of façade)

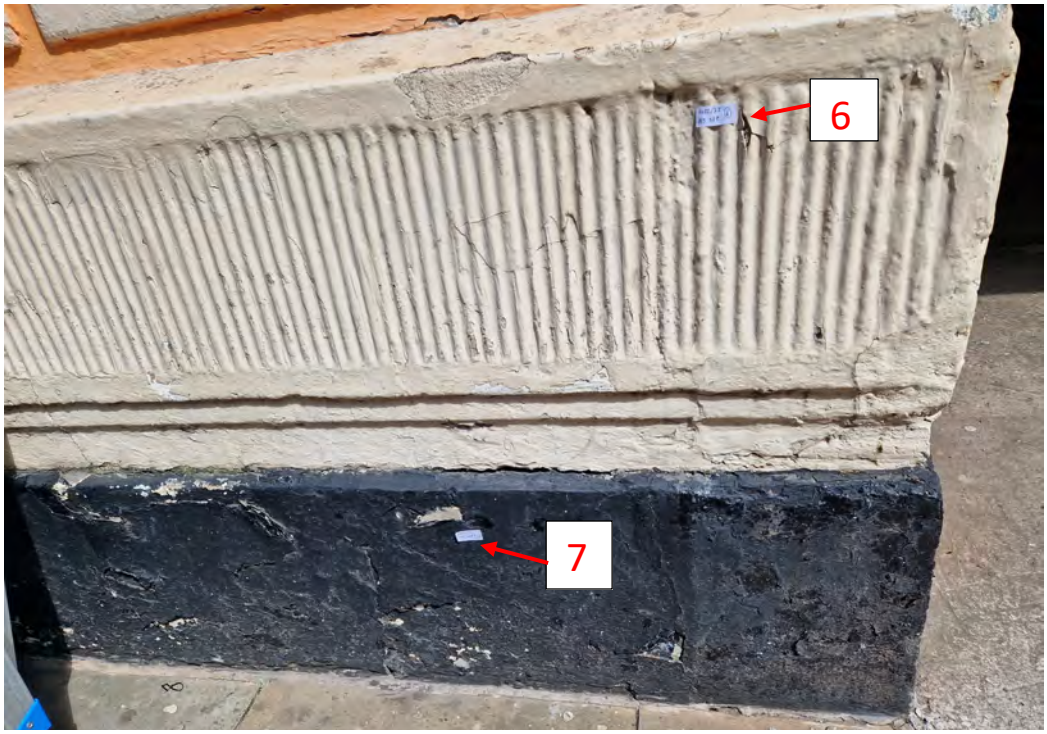


Figure 7: sample locations 6 & 7 (fluted course and flat plinth of lower façade)

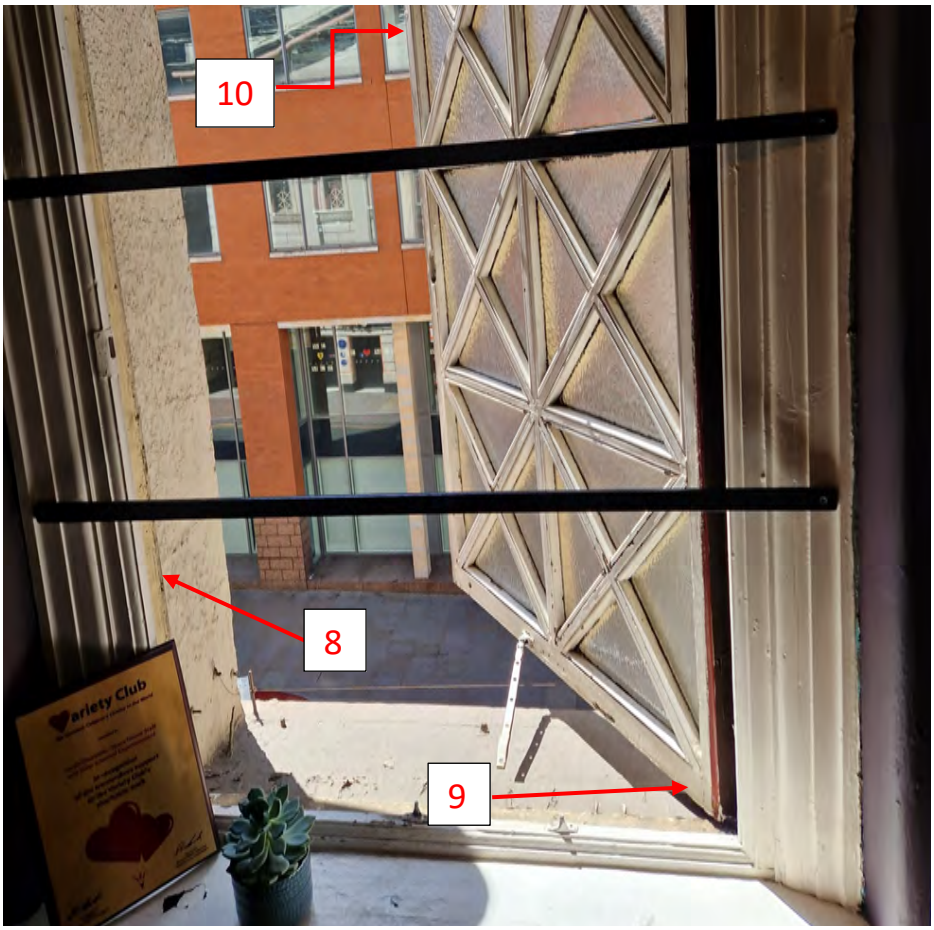


Figure 8: sample locations 8-10 (upper window W13-LG)

Figure 9: sample location 11 (upper window W11-LG)

Figure 10: sample location 12 (upper window W8-LG)

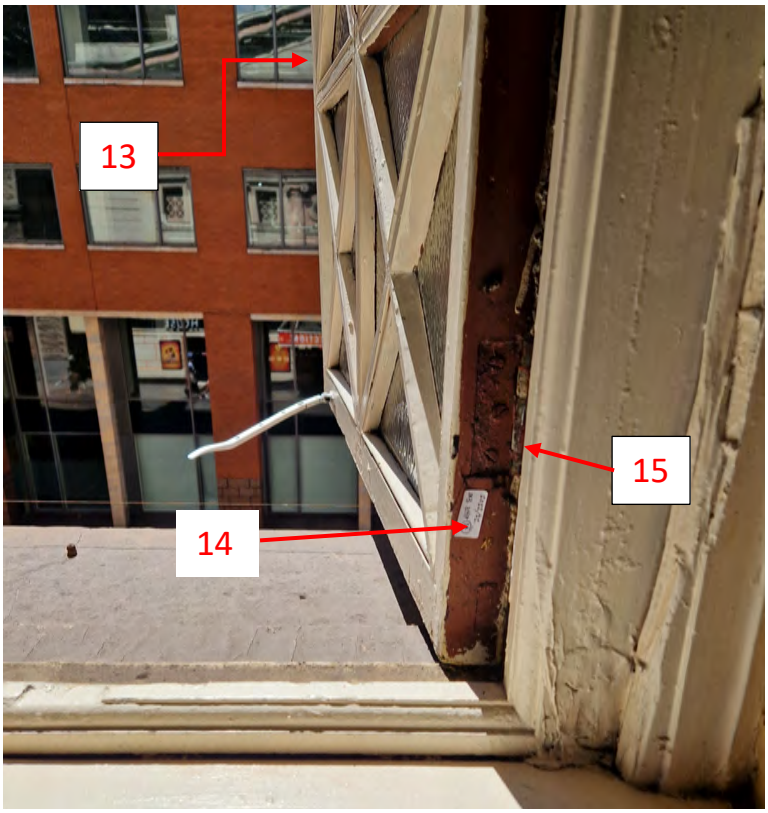
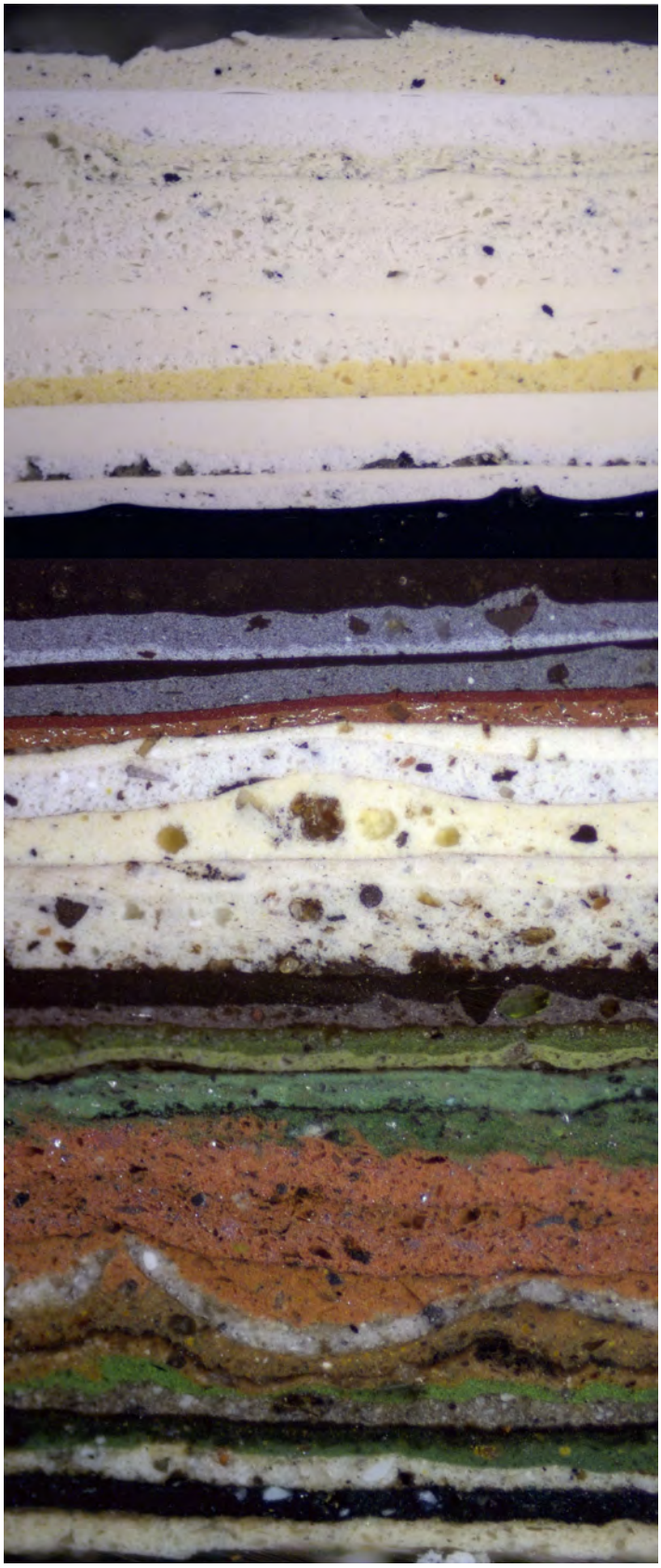


Figure 11: sample locations 13-15 (upper window W15-LG)

Figure 12: sample locations 16 & 17 (upper window W16-LG)

5.0: Sample photomicrographs

5.1 Windows



Post war
c.1950 – present

The later schemes begin with a bright red alkyd paint, followed by several schemes of black, and finally by mainly white, off-white and cream alkyd and zinc paints. The single scheme of yellow alkyd paint may date from the 1960s, when programme covers show that the Opera House may have been given a predominantly yellow decorative treatment (see Figure 4).

Pre-war c.1912-1940

The earliest layers are lead oil paints in strong colours: initially blue/black, then mid-green, tan brown and red. These were often refreshed once or twice between colour changes. These are followed by off-white and cream zinc paints, which may date to the 1930s or 1940s.

*Figure 13: **Sample 3**, exterior window casement W1-F*

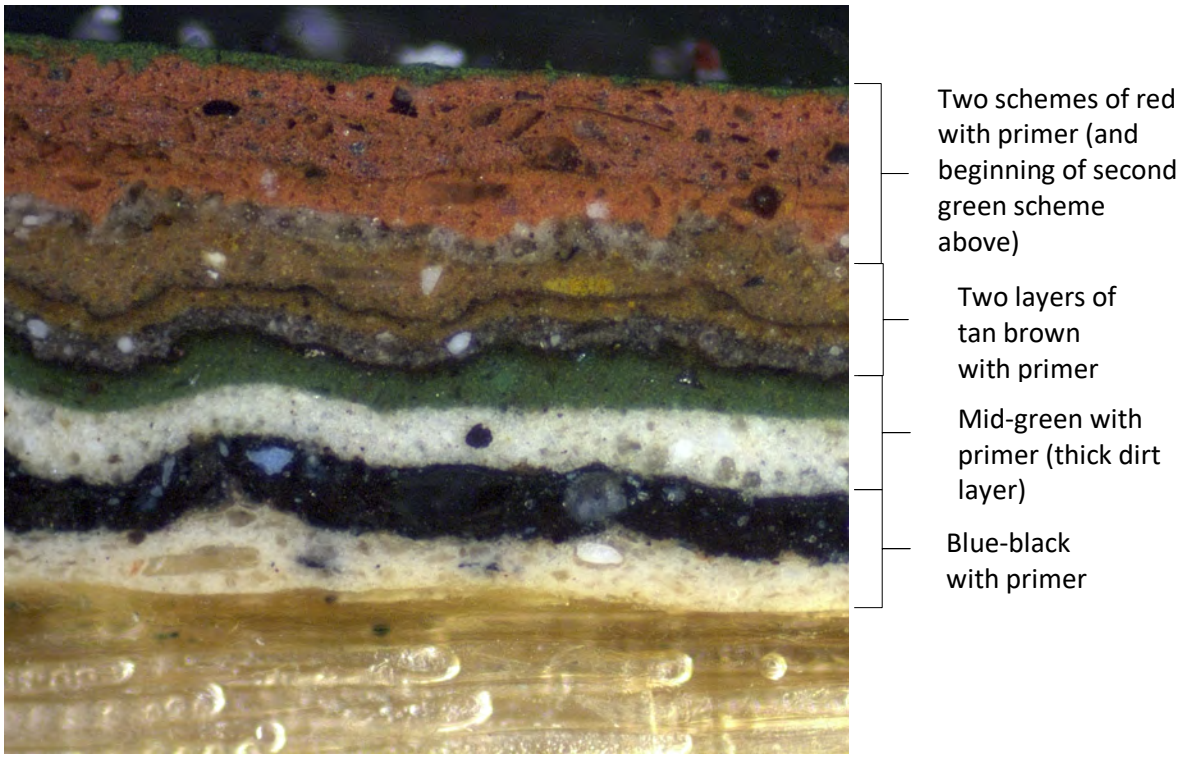


*Figure 14: Close-up of **Sample 1**, exterior window casement W2-F, showing earliest paint layers on wood substrate*

All of the samples from the window exteriors, both upper and lower, show similar stratigraphy: early lead paints in blue-black, mid-green, tan brown and red, followed by off-white and cream lead and zinc paints, then black zinc paints, then more off-white and cream paints, mainly zinc and alkyd (with a single layer of yellow in the later layers). This stratigraphy is the same for both the casements and the frames, suggesting that they have been painted the same colour throughout their decorative history.

The use of strong colours in the early layers is typical of external decoration on urban buildings in the late 19th and early 20th centuries, when high levels of air pollution in city centres meant that pale colours would appear soiled very quickly. The first mid-green scheme shows a thick dirt layer on the surface, illustrating this problem, and suggesting that it was in place for longer than some of the later schemes.

The large number of layers (approximately 24 schemes) indicates that the windows were repainted or refreshed roughly every 4-5 years throughout the building's history. This may be due in part to the abovementioned problem of pollution.

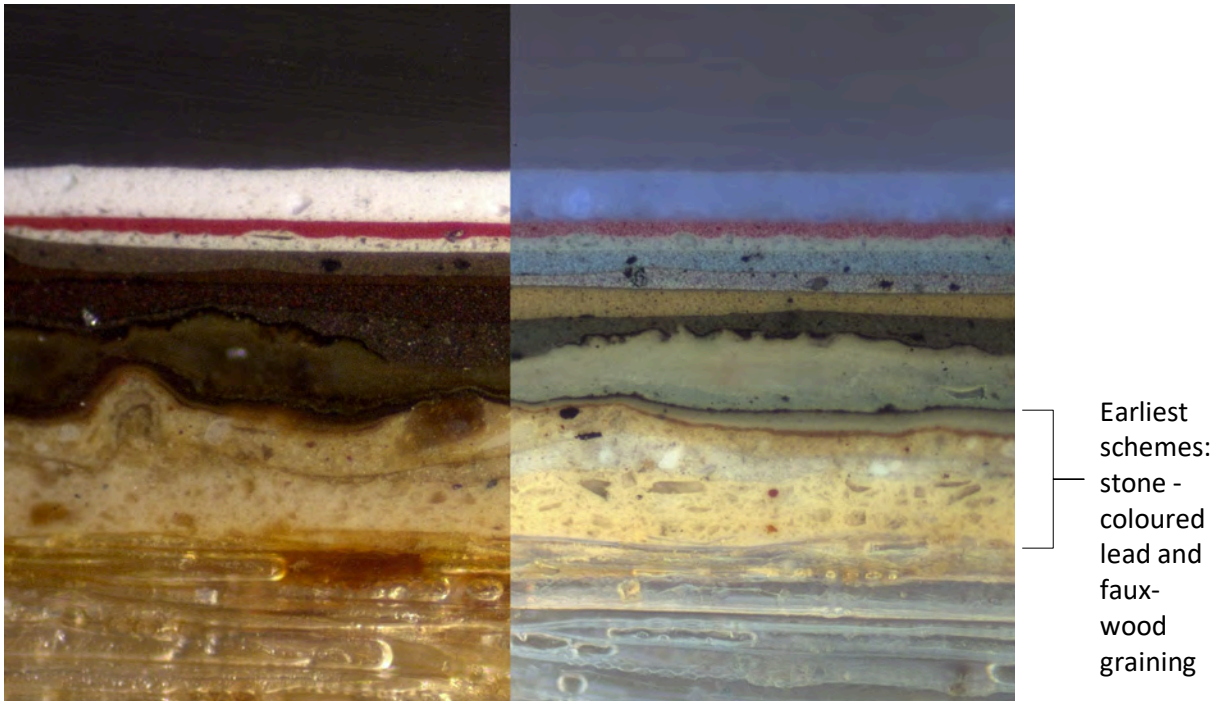


*Figure 15: **Sample 9**, interior casement of W13-LG (right is under UV light)*

The samples taken from the interiors of the upper windows show that the earliest decorative scheme was a stone-coloured lead paint, followed by a faux-wood-grained finish (which is common in late 19th and early 20th century interior decoration), and later covered by several layers of varnish. This was followed by several different shades of brown zinc paints, and lastly by a layer of red zinc paint, before the current layer of modern white paint was applied.

This indicates that the interiors of the windows were treated differently from the exteriors, and that the decorative schemes used on the insides of the windows were more likely related to the interior decoration of the Opera House.

5.2 Facade

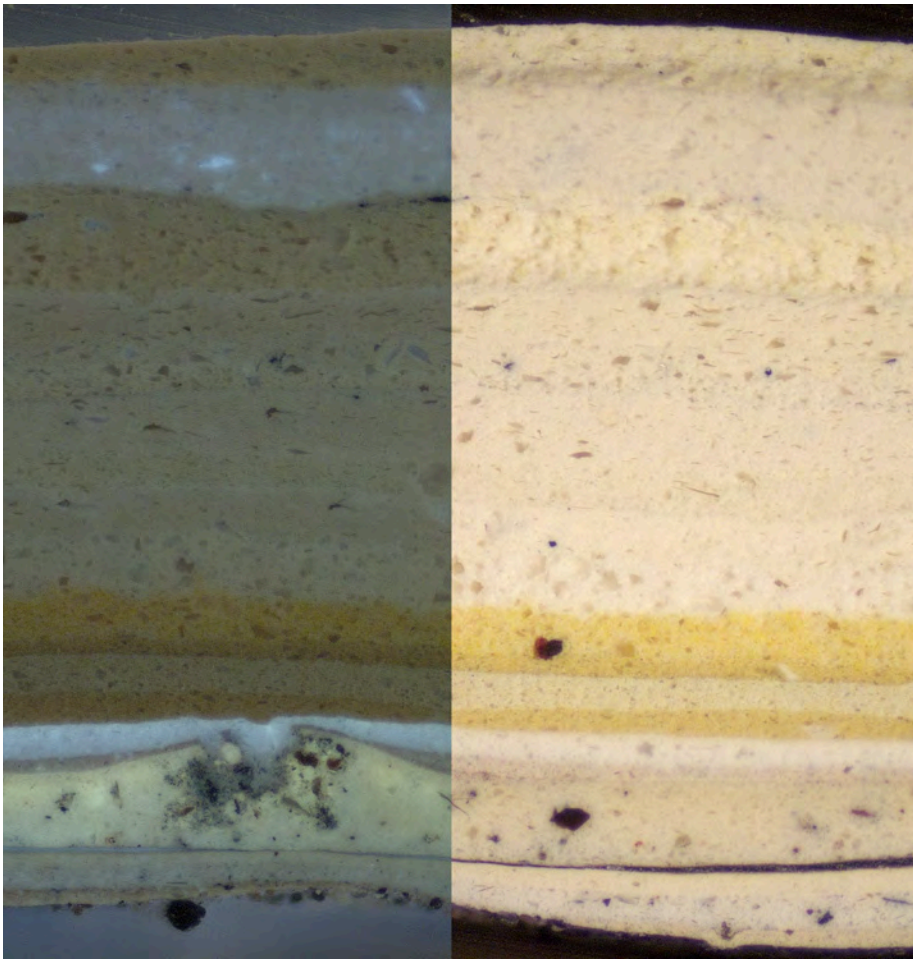


*Figure 16: **Sample 4**, façade stucco (left is under UV light)*

The sample taken from the façade stucco shows only more recent zinc and alkyd paints, suggesting that either the façade has been cleaned of paint in the past, or that that it was initially unpainted only to be painted in a pale stone colour later, when surfaces appeared weathered and deemed unsightly. It is worth noting that residues of blue paint were seen in some areas of the façade on site, but these do not appear in the sample taken.

The sample shows that the earliest visible layers are pale stone-coloured zinc paints, which may date from the period just before or just after the Second World War. The yellow alkyd paints that follow may date to the 1960s, when theatre programmes from the Opera House show the exterior of the building to be predominantly yellow (see Figure 4), although as this is an artist's interpretation, it may not be entirely accurate. The rest of the layers are mainly off-white and pale stone-coloured alkyd paints.

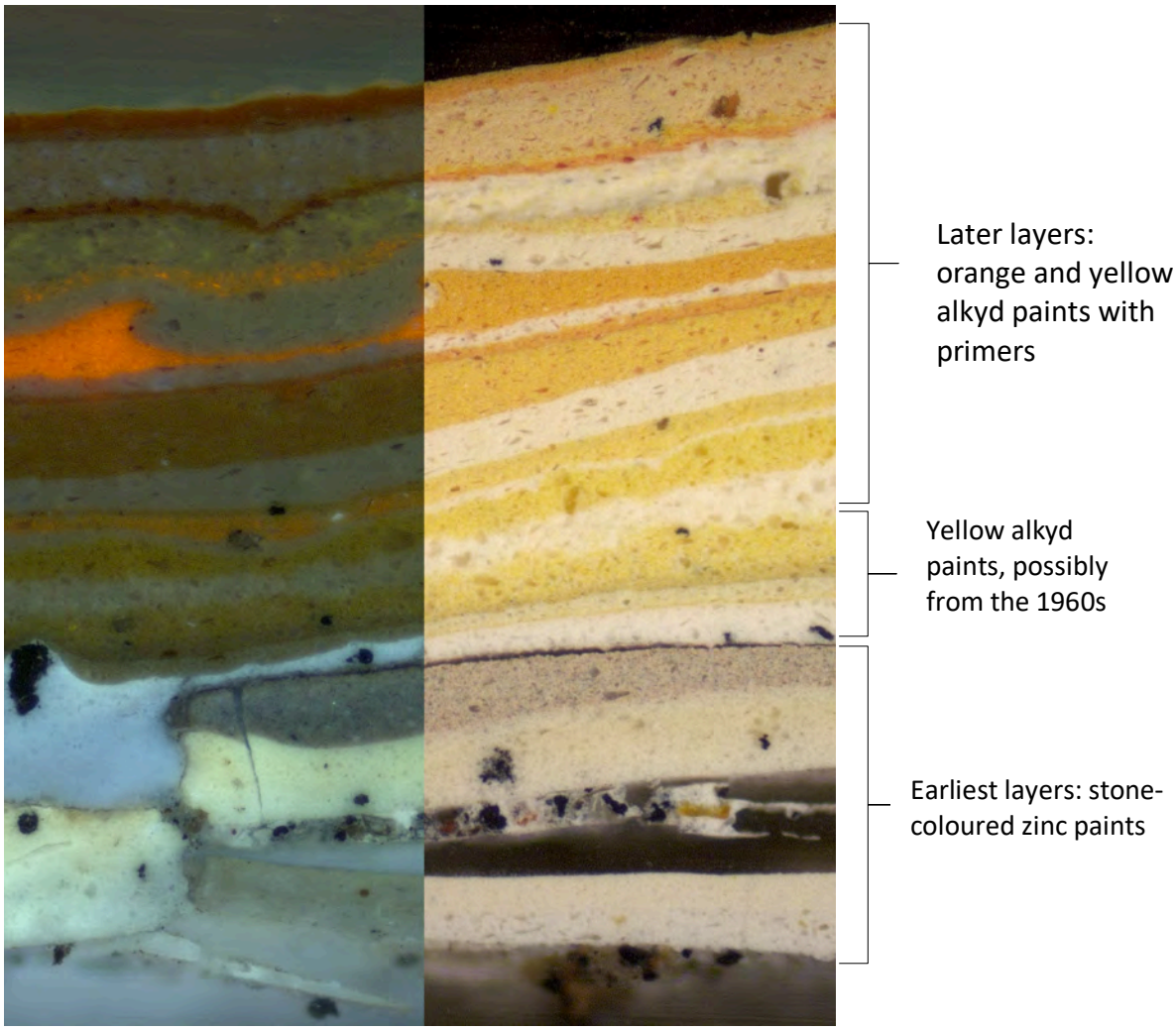


*Figure 17: **Sample 5**, joints between faux-ashlar blocks on façade (left is under UV light)*

The sample taken from the joints between the faux-ashlar blocks of the façade shows a similar early stratigraphy to the sample from the blocks themselves: the earliest layers are stone-coloured zinc paints, followed by the same yellow alkyd layers as on the blocks, which may date to the 1960s. Above these yellow layers, however, the sample shows that the yellow alkyds continued for two more schemes, and then were changed to orange or yellow-orange alkyd paints.

This suggests that the joints have often been picked out in yellow or orange (with the blocks themselves being painted in lighter off-white or cream colours) since the 'yellow scheme' of the 1960s. Before this period, however, it is uncertain whether the joints were painted differently from the blocks, although the presence of a slightly darker stone colour in the earliest layers may support this for the period of the stone-coloured zinc schemes.

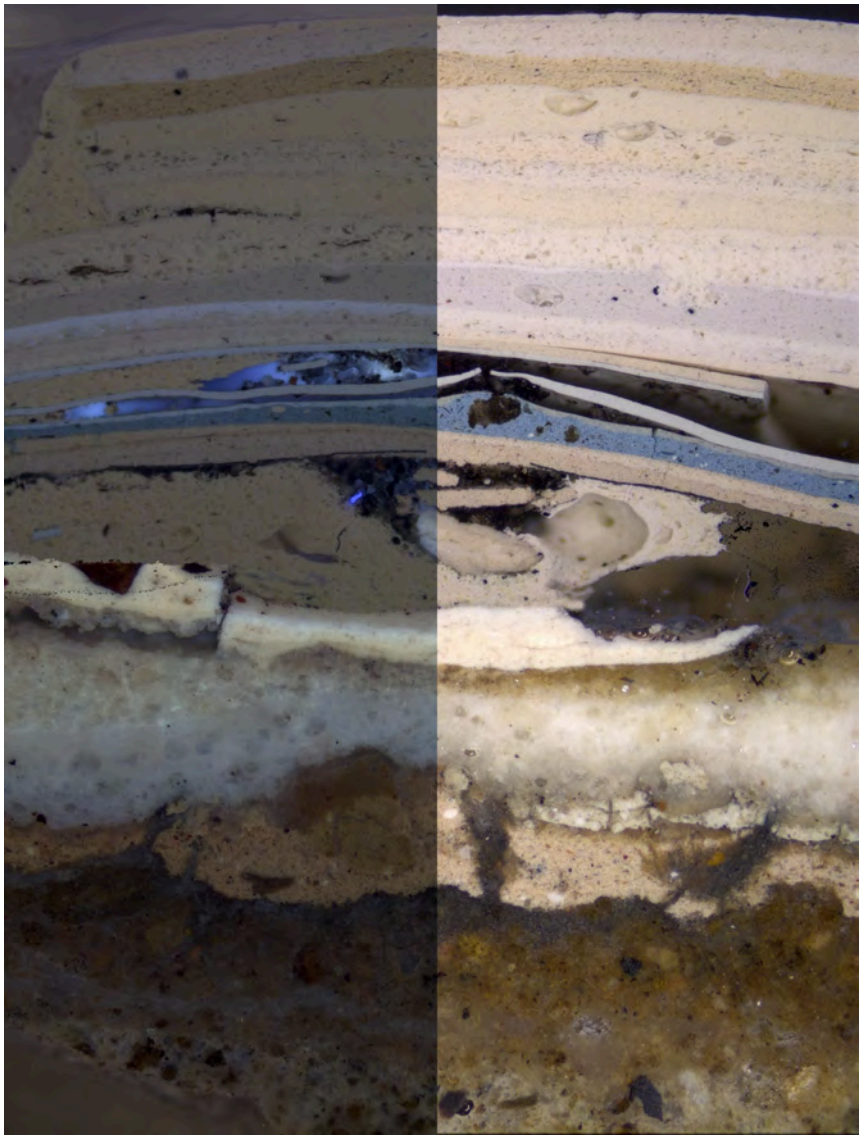


*Figure 18: **Sample 6**, fluted course, lower façade (left is under UV light)*

The sample from the fluted course below the faux-ashlar blockwork shows an early layer of mid-brown just above the substrate; this layer may be the original render colour, or it may be a coating added later in the building's history, but the heavy dirt layer on it suggests that it was in place for some time. This is followed by traces of white and stone-coloured paint, which appear similar to later layers, and may have seeped down to this level through cracks in the layers above. These are followed by two layers of white limewash, and then by several layers of white lead oil paints. The next schemes are a series of stone-coloured zinc paints, which appear similar to the earliest layers on Samples 4 and 5, and may date to the

same period in the mid-20th century. Within these stone-coloured layers, however, are layers of pale blue and mid-blue, indicating that this element of the façade may have been picked out in blue tones at some point in the mid-20th century. These layers may also relate to the blue paint residues seen elsewhere on the façade during the sampling visit. The final layers are all modern alkyd paints in pale colours: pale grey, off-white, pale stone and cream.

This suggests that the fluted course has been painted in pale colours throughout much of its history, but it was painted to match the blocks in the façade above in some schemes, and picked out in toning colours (such as blue or grey) in other schemes.

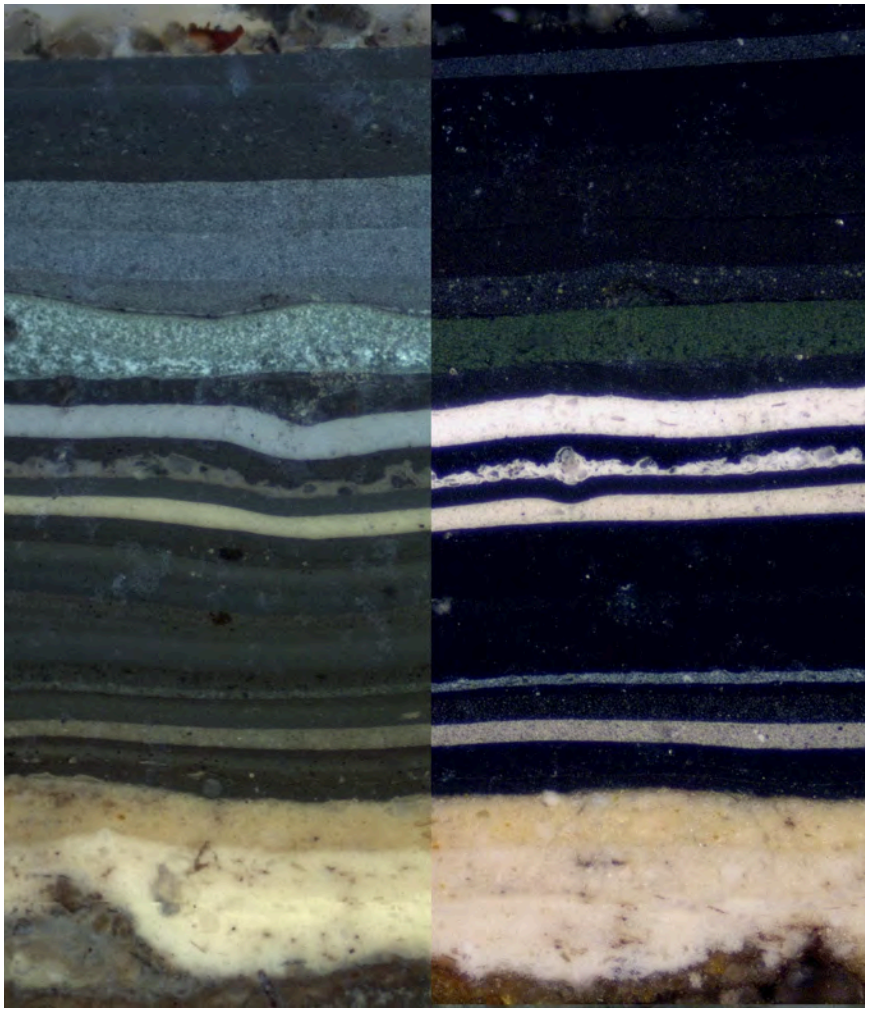


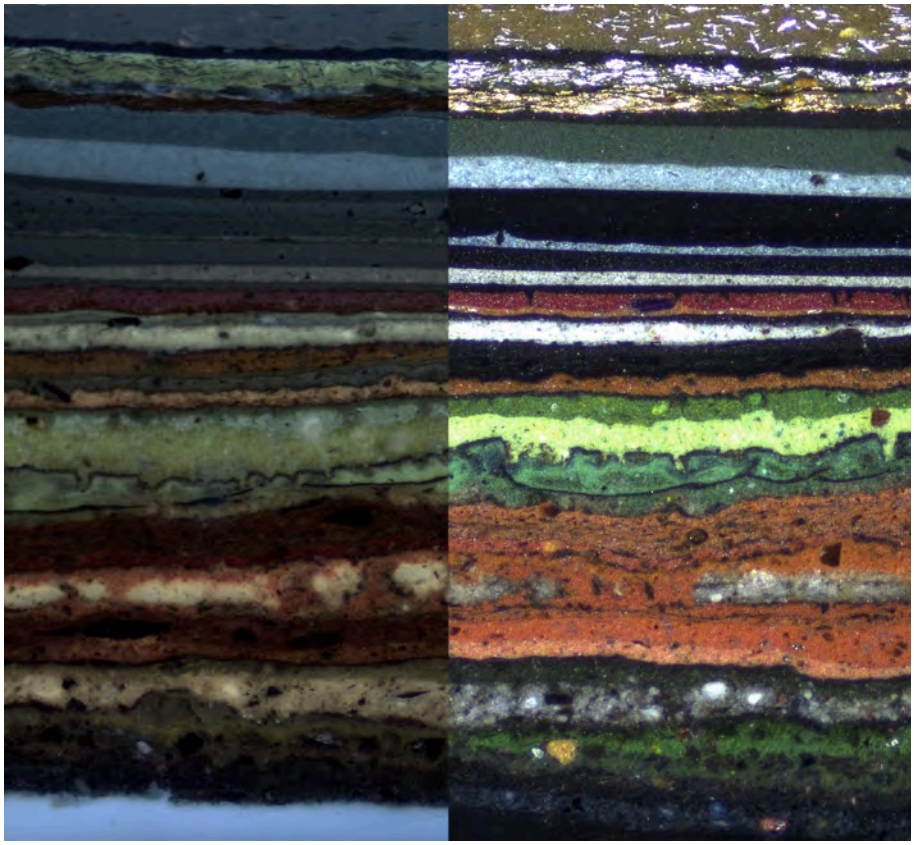
*Figure 19: **Sample 7**, flat plinth at base of façade (left is under UV light)*

The sample removed from the flat plinth at the base of the façade shows a somewhat different stratigraphy to the elements above it. The earliest layers are traces of a brown

coating, which appears to be the same as the early brown layer on Sample 6 from the fluted course above, with a pale yellowish-stone-coloured lead paint above it. These may relate to the decorative treatments of the façade up to the 1960s, as archival photographs (see Figure 3) and programme covers (see Figure 4) show this element painted in light colours up to 1968, and painted in dark colours from the 1970s onwards. The disturbed surface of the brown layer, however, may indicate that the surface has been scraped back before the application of the yellowish-stone lead paint, so any intervening layers may have been lost. The later layers are mainly black paints with primers: the zinc-based paints are likely to date from the mid-late 20th century, while the black alkyd paints are likely to be late 20th- 21st century.

The resemblance of the early brown finish to the earliest layer in Sample 6 above suggests that the lowest two elements on the façade may have been treated similarly in early decorative schemes.

5.3 Railings



Post-war: c.1950-present

Railings are initially painted the same as windows, but later painted separately

Pre-war: c.1912-1940

Railings are painted the same as exterior windows

*Figure 20: **Sample 18**, finial of railings (left is under UV light)*

The samples removed from the railings show almost the same early stratigraphy as the samples removed from the exterior windows, with the same early colours of blue-black, mid-green and red lead paints (only the tan brown is missing). This similarity continues into the early post-war period, with the same bright red followed by several layers of black, before diverging from the window schemes around the 1960s, when the railings were painted a dark green (possibly during the yellow façade period), and then the finials were picked out (for the first time) in metallic paints.

This indicates that the railings have historically been painted the same colour as the exterior window frames, and that for the majority of their history, the finials were painted the same as the rest of the railings.

6.0: Discussion

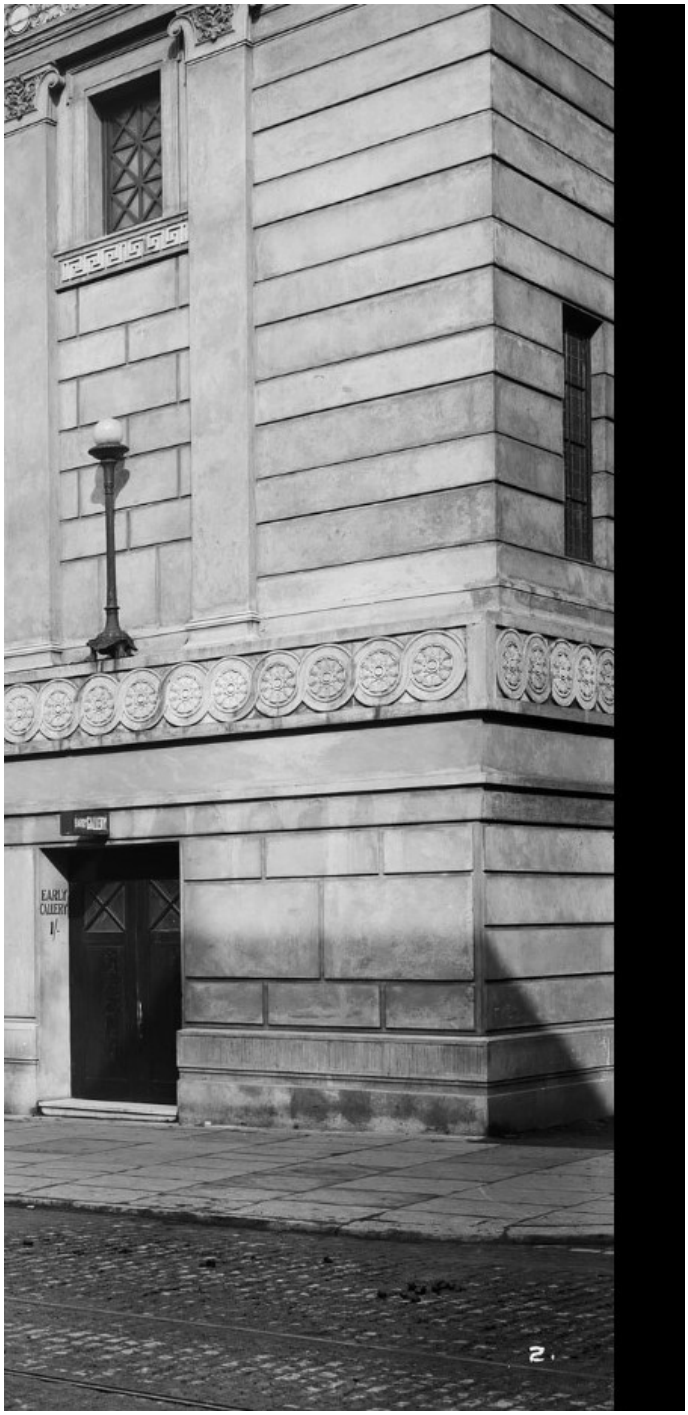


Figure 21: Detail of the Opera House in 1913, showing window & facade treatments (source: Historic England)

The decorative history of the Opera House's exterior is difficult to determine with precision, but our research has highlighted several key points.

6.1: Colours

The external elements of the windows were originally painted in strong colours, firstly blue-black, then mid-green, tan brown and red. This can be seen in Figure 21, where the window frame and casement are clearly considerably darker than the surrounding façade. These colours were a practical choice, given the high levels of sulphurous air pollution in Manchester in the early 20th century. Both window frame and casement were painted in the same colours during this early period.

The interior faces of the window casements were originally painted pale stone, then given a faux-wood-grained finish, likely linking them to decorative schemes within the interior of the building, rather than to the exterior decorative treatments.

The absence of early paint evidence on the façade stucco, coupled with early images of the exterior, strongly suggests it was originally left unpainted. The first paint scheme in pale stone was applied just before or after World War II, probably because the building's appearance had become stained and blackened due to atmospheric pollutants. The surfaces of the façade in the 1913 photographs below (fig.22) appear to be entirely unpainted.

Figure 22: detail of the Opera House in 1913, showing railings (source: Historic England)

The railings on the corner of the façade were originally painted the same as the exterior windows, in a single colour. Photographs from 1913 appear to show much of the exterior metalwork painted the same dark colour as the windows (see Figure 22), so it is likely that the railings were included in this comprehensive exterior decorative scheme.

6.2: Materials

6.2.1: Wood

Analysis of wood samples removed from the windows was carried out to determine the precise species used in their construction[4], using microscopic examination under both reflected and transmitted light. Comparison with known samples showed that the wood was **Scots pine (*pinus sylvestris*)** (see Appendix 1). This is supported by the discovery of wood-graining on the interior of the window casements, since wood-graining was used in the 19th and early 20th centuries to make cheaper softwoods (like pine) resemble more expensive hardwoods (like mahogany or figured oak).

6.2.2: Render

Analysis of a stucco sample removed from the exterior façade was carried out by light microscopy and powder x-ray diffractometry (pXRD) to determine the nature of the stucco material itself and aggregates used[5]. This analysis showed that the render used on the exterior of the building was **Ordinary Portland Cement** (see Appendix 2).

6.2.3: Lead

Ultra-violet fluorescence and micro-chemical analysis with sodium sulphide during microscopic examination indicated that the early paint layers on the windows and railings contain high levels of lead. Lead was added to traditional oil paints as a pigment (e.g. lead white or red lead oxide) to impart colour, or to act as a siccative to speed the drying process. Lower levels of lead were also detected in the earliest layers on the façade. As a result, any work done that disturbs these early paints will need to comply with HSE regulations (Control of Lead at Work (CLAW)).

[4] Analysis carried out by Henning Schulze, Senior Lecturer University of Lincoln
[5] Analysis carried out by Dr Nicholas Riess, Project Scientist University of Lincoln

Appendix 1: Wood Analysis

Wood Identification

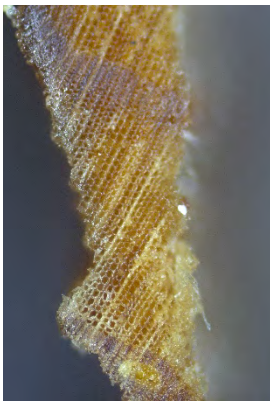
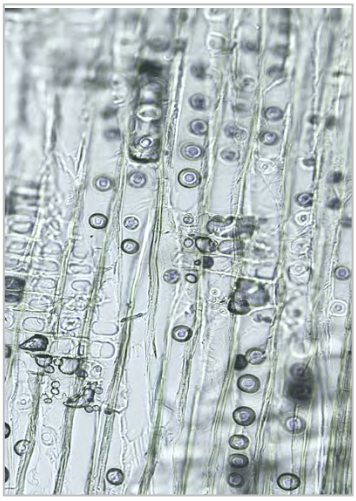
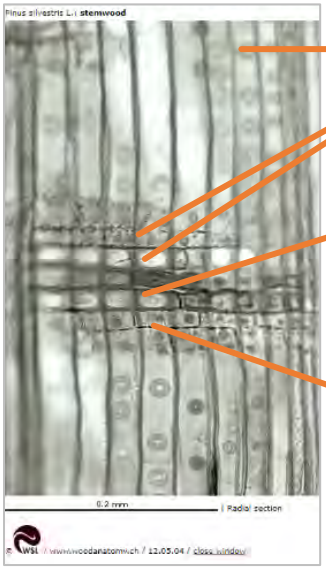
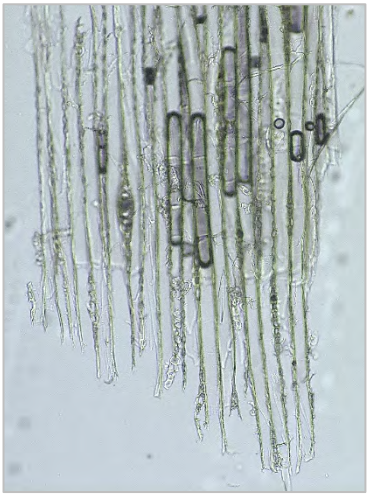
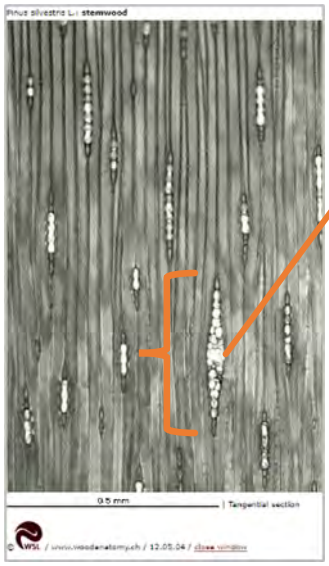
Wood identification had to rely on microscopic features as all surfaces of the windows are coated with paint and were hence not accessible for assessment of macroscopic features. Using small samples taken on site (Sample identifier W 16 LG), the identification followed standard methods by preparing microscopic slides to examine cross, tangential, and radial sections. Sections were examined under reflected light (Cross-section 10 x magnification) and transmitted light
(Radial and tangential sections 50 x to 100 x magnification) and compared with reference samples (Schoch et al).

The species identified for this sample is Scots Pine (*Pinus sylvestris*).

Microscopic features	Observations	Result
Cross section (X)		
Vessels/pores	Absent	Softwood
Growth ring boundaries and transition from early to late wood	Boundaries distinct, transition abrupt	
Resin canals	Sparse but present in mostly in late wood, large	
Radial section (R)		
Tracheid pits	Uniseriate	
Rays	Present, heterocellular	
Ray tracheids	Distinctly dentated walls	
Cross-fields from parenchyma cells to tracheids	Single fenestriform pit	
Tangential section (T)		
Rays	up to 15 cells high	
Resin canals in rays	Thin-walled epithelial cells	

A tree species sharing similarities in some features is Douglas fir *(Pseudotsuga menziesii).* Due to the absence of distinct spiral thickenings (expected to be visible in R and T sections) and absence of taxoid and piceoid cross-filed this species could be ruled out.

Schoch,W.,Heller,I.,Schweingruber,F.H.,Kienast,F.,2004:Wood anatomy of central European Species. Online version:www.woodanatomy.ch, accessed 06/09/2022

Sample W 16 LG	Reference images	Features
	 *Cross section 10 x magnification*	• Pores/vessels absent • Growth ring boundaries distinct • Transition early to late wood abrupt • Resin canals sparse but present in mostly in late wood, large
 *Radial section 100 x magnification*	 	• Tracheid pits uniseriate • Rays heterocellular • Cross-fields from parenchyma cells to tracheids with single fenestriform pits • Ray tracheids distinctly dentated walls
 *Tangential section 50 x magnification*	 	• Rays up to 15 cells high • Resin canals in rays with thin-walled epithelial cells

Appendix 2: Render Analysis

1. Executive Summary

A sample of exterior stucco was removed from Manchester Opera House for analysis, with a view to understanding the composition of the stucco coating; whether a lime or cementitious material, mix ratio and aggregate sizes. This will help to prescribe a suitable repair mix that is compatible with the historic material.

In order to achieve this, aggregate and binder portions were physically separated and then analysed by powder X-ray diffractometry (pXRD). The resulting diffraction patterns were cross-referenced against a database in order to determine the dominant and minor phases present.

2. Methodology

Light Microscopy/ pXRD

A small portion of the sample was removed and ground by hand to an even powder. A portion of the powder (~5g) was sieved, initially through a 1.7mm sieve to remove any unbroken mortar and then through 0.140 mm and 0.045 mm sieves respectively. For the purposes of pXRD analysis that fraction of the sample which was retained by the 0.140 mm sieve was designated aggregate whilst that fraction passing through the 0.045 mm sieve was determined to be binder. For the determination of aggregate and binder masses, that fraction which was > 0.045mm was designated aggregate whilst material < 0.045 mm was determined to be binder.

The two fractions were imaged using a Discover.V8 light stereo microscope (ZEISS) at x40 magnification. The sieved aggregate/ binder fractions were then analysed using powder X-Ray diffraction. *X*-Ray diffraction data were collected with a Bruker D8 Discover operating in with parallel beam geometry collimated to 2 mm beam with Cu-Kα radiation (λ = 1.5406 Å). Data were collected were collected from three separate sample sites with coupled θ-2θ scans in the 2θ-range 5-80° with dwell time of 0.2s for each 0.02° increment. Data were merged for analysis.

3. Results

Light Microscopy

Visual inspection of the aggregate showed that the material was of fairly consistent grain size, typically around 0.5mm in diameter with occasional larger grains, up to 1mm in size (Figure 1). The binder fraction was an off-white. beige powder with darker/ black specks apparent throughout.
The calculated aggregate: binder ratio was 3.5/4 to 1 (Table 1).

Table 1. *Indicative aggregate:binder ratios by weight and by volume. The mass of the aggregate fractions retained by the 1.7mm sieve are shown in brackets.*

Aggregate		Binder		Aggregate:Binder ratio		Approx. Aggregate Grain size
(g)	(cm^3)	(g)	(cm^3)	By weight	By volume	mm
3.01	2.51	0.84	0.64	3.6:1	3.9:1	0.5-1.0

X-Ray Diffraction

The results from the powder X-ray diffraction analysis are summarised in Table 2. Quartz sand was the dominant phase present in the aggregate with calcite also present in trace amounts. Quartz was again the major phase in the binder, this time alongside calcite. In addition, alite was present as a minor phase along with belite in trace amounts and possibly tricalcium aluminate.

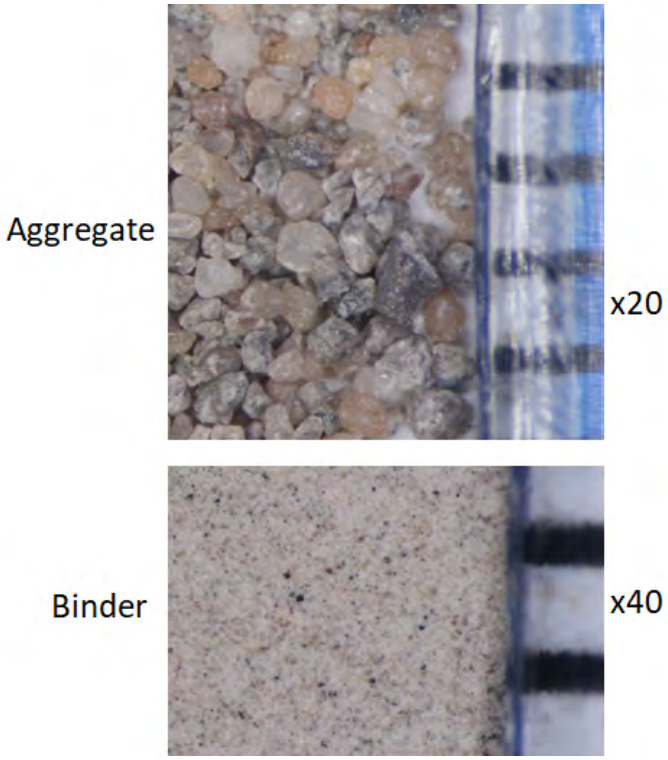


Figure 1. *Micrographs (x20/40) of the ground mortar samples. Ruler on each image shows a millimetre scale.*

***Table 2**. Mineral phases present in the mortar samples.*

BLPr_00062	a = aggregate, b = binder		001a	001b
Calcite		$CaCO_3$	++	++++
Quartz		SiO_2	+++++	++++
Alite	C3S	Ca_3SiO_5		+++
Larnite	C2S	β-Ca_2SiO_4 (belite)		++
Tricalcium aluminate	C3A	$Ca_3Al_2O_6$ or $3CaO{\cdot}Al_2O_3$ (aluminate, celite)		+
Gypsum	CSH2	$CaSO_4{\cdot}2H_2O$		
Jennite	CSH	calcium silicate hydrate $Ca_9(Si_3O_9)_2(OH)_8{\cdot}8H_2O$		
Tobermorite	CSH	calcium silicate hydrate CaH_2SiO_4		
Suolunite	CSH	calcium silicate hydrate $Ca_2(H_2Si_2O_7){\cdot}H2O$		

Key: +++++ dominant, ++++ major, +++ minor, ++ trace, + possible, * orientated

4. Summary

Visually the aggregate appeared consistent with a sand aggregate and quartz was indeed detected in the PXRD analysis further indicating that the aggregate was sand-based. The sand used was of consistent composition with grains around 0.5mm in diameter widespread. The detection of calcite in the aggregate is likely due to the residual mortar observed visually on the sand grains.

The binder fraction was dominated by quartz, unusually. This may be due to small quartz shards passing through the fine sieve resulting in the larger multi-coloured particles observed visually via light microscopy. It is not clear how such shards would be created, however. They are not usually seen in typical mortar samples which indicates that the grinding process used has not created them. It is possible that the small quartz particles/ shards were present in the original aggregate or else were created by the mixing/ application of the screed mortar.

The observation of alite together with belite and the possible presence of tricalcium aluminate all indicate the mortar is an **Ordinary Portland Cement** (OPC).

HISTORIC MATERIALS ANALYSIS

HISTORIC INTERIORS

ARCHITECTURAL CERAMICS AND TILES

OBJECT CONSERVATION

DIGITAL HERITAGE

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